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NOTES ON GEOGRAPHIC DISTRIBUTION

On correct identification, range expansion and management implications of *Myriophyllum aquaticum* in Kashmir Himalaya, India

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ABSTRACT: The misidentification of *Myriophyllum aquaticum* (Vell.) Verdc. in the Kashmir Himalaya, India is corrected. In addition to its taxonomic description and illustration, the paper discusses the range expansion of this invasive plant species into different aquatic habitats and management implications in the region.

Haloragaceae R. Br. comprises eight genera and *ca.* 120 species of extremely diverse habit, ranging from small trees to submerged macrophytes (Moody and Les 2007). The genus *Myriophyllum* L. is distinct within Haloragaceae due to its characteristic fruits that split at maturity into two or four individual nutlets (Orchard 1986). *Myriophyllum* species are rooted, submerged to emergent macrophytes, with irregularly branched shoots, and whorled leaves with pinnatisect blades having filiform segments.

Myriophyllum (watermilfoil) is among the more species rich (68 spp.) genera of the aquatic "Core Eudicots" (APG II 2003). It is distributed world-wide (except Antarctica) with a centre of diversity in Australia (42 spp.; 37 endemic). North America (14 spp.; seven endemic) and Asia (16 spp.; eight endemic) also have high continental diversity and share seven common species (Moody and Les 2010). Five *Myriophyllum* species have been reported from the Indian subcontinent (Hooker 1879). In Kashmir Himalaya, located in the northwestern extremity of Indian Himalayas, Kak (1990) reported three species of the genus from the region: *M. spicatum, M. tuberculatum* and *M. verticillatum*. Cook (1996) also reported a non-indigenous species *M. aquaticum* occurring around Dal Lake in the region. However, while carrying out the field studies on the genus *Myriophyllum* in the Kashmir Himalaya, we came across a *Myriophyllum* species hitherto incorrectly identified and one that is fast naturalizing in various aquatic habitats. After detailed comparative taxonomic analysis, this distinctive species was identified as *M. aquaticum* (Table 1.). On further investigation, we found many specimens of *M. aquaticum* in the Kashmir University Herbarium (KASH), which had been deposited over the last four decades, but were misidentified as *M. verticillatum* and *M. spicatum* (see Specimens examined). All of these specimens have now been annotated correctly.

Global distribution: *M. aquaticum* is a native of South America, but has become naturalized almost worldwide. The species now occurs also in Australia, China, England, France, Indonesia, Japan, Madagascar, Malaysia, Mexico, New Zealand, Nicaragua, Philippines, South Africa, United States, and Zimbabwe (Li and Hsieh 1996)

Although *M. aquaticum* is dioecious in its native range of South America, only female plants were found in the Kashmir Himalaya during the present study. This paper corrects the taxonomic identification and documents the range expansion of *M. aquaticum* in the Kashmir Himalaya and provides a taxonomic description and illustration. Because this nonindigenous species spreads as invasive as observed during the present study, we also discuss briefly the management implications of this range expansion into the Kashmir Himalaya region.

Distribution Pattern in Kashmir Himalaya

Although Cook (1996) reported the occurrence of *M. aquaticum* around the Dal lake in Kashmir Himalaya, since then the species has now spread all over the region, including the two Ramsar sites of Wular and Hokarsar; Anchar, Manasbal, and Hygam wetlands, and in almost all of the springs, ponds, marshes and irrigation channels. Because this species has naturalized in these various aquatic habitats so quickly, it is likely to become even more invasive in the future.

It has been observed that *M. aquaticum* inhabits edges of streams, lakes, ponds, ditches and irrigation canals but preferably colonizes lentic (*i.e.* slowly-moving) waters. It grows best when rooted in shallow water and rarely inhabits water bodies with a depth greater than one meter. Due to the formation of abundant populations spread over large areas, the species seems to inhibit the occurrence and growth of associated macrophytic vegetation in the region. This aggressive growth likely enables the species to form large homogenous patches, which can dominate the aquatic habitats (Figure 1A.).

Taxonomic Information

Myriophyllum aquaticum (Vell.) Verdc. *Kew Bull.* 23: 36.

1973. (Figures 1 and 2).
Basionym: *Enydria aquatica* Vell., *Fl. Flumin.* **57**. 1825.
Synonyms: *Myriophyllum brasiliense* Cambess.; *M. proserpinacoides* Gilles ex Hook. and Arn.
English names: Parrot-feather, Brazilian water-milfoil.
Vernacular names: '*Hill', 'Shill'*

Perennial erect herb. Rhizomes tough, terete, 3-9 mm in diameter with prominent nodes and internodes, adventitious roots arising at each node. Stem 40-90 cm long, 4.0-5.0 mm in diameter, flexible, cylindrical, glabrous and green in colour; the lower internodes 0.2-5.1 cm, longer than the upper ones 0.1-0.3 cm. Leaves whorled, slightly dimorphic; submerged leaves in whorls of 3-6, oblanceolate in outline, rounded at apex, 3.1-4.0 cm long, 0.6-1.1 cm wide, pectinate, with 9-26 linear pinnae up to 5.5 mm long; emergent leaves glaucous, in whorls of 3-6, erect near apex, 1.0-3.0 cm long, 0.4-0.8 cm wide, pectinate, with 18-30 pinnae upto 0.7 cm long; pinnae are linear-subulate, tips very shortly apiculate, slightly incurved. Female flowers inconspicuous, born in the axils of middle and upper emergent leaves, tetramerous, pedicel 0.2-0.5 mm long. Bracteoles white, subulate dilated at base, sometimes with 1 lacinia, 0.5-1.5 mm long. Sepals 4, white, deltoid, 0.3-0.5 mm long, 0.1-0.3 mm wide, acute, entire or scarcely serrate. Petals reduced. Styles 4, clavate, 0.1-0.2 mm long. Stigmas white, densely fimbriate, ovary pyriform 0.5-0.6 mm wide.

Figure 1. A) Population of *Myriophyllum aquaticum*. B) An individual plant. C) Close up of a female flower.

Flowering period: April-June.

Species Accounts

Specimens examined (all at KASH): INDIA: Kashmir: Dal lake. (1585m asl, 34°60' N, 74°80' E)15-05-2009, *Arshid and Ganie 9901*. Anchar lake. (1584m asl, 34°23' N, 74°90' E) 01-06-2009, *Arshid and Ganie 9902*. Wular lake. (1580m asl, 34°20' N, 74°44' E) 06-07-2009, *Arshid and Ganie 9903*. Sundoo stream. Anantnag, (1661m asl, 34°41' N, 75°11' E) 10-04-2010, *Arshid and Ganie 990*. Flood channel, Narbal. (1583m asl, 34°60' N, 74°12' E) 23-04-2010, *Arshid and Ganie* 9905. Mansbal lake (1584m asl, 34 15' N, 74 41' E) 27-04-2010, *Arshid, Wani, Ganie and Khuroo 9906*.

Newly annotated material (previously misidentified): Shal Teng. 1580m, 25-8-1968, *GNJ 784*; *Bemina 1600*; 27-8-1973, *A.M.Kak 696*. Kujar. 1625m, 19-11-1981, *G.H.Dar 3309*. Chogal, 28-8-1984, *M.A.Hakeem 82*. Dal lake. 1585m, 11-3-1995, *Bilqees Chashoo 59*; *Bilqees Chashoo 60*; 15-6-2003, *Fehima Gul s.n.*

Management Implications

Some *Myriophyllum* species (*e.g. M. aquaticum, M. heterophyllum, M. spicatum*) are notoriously invasive in global aquatic ecosystems (Moody and Les, 2010). *M. aquaticum* has spread to other regions of the world mainly through the pathway of aquaria trade (Rixon *et al.* 2005). At present, such aquatic invasive plants have caused devastation to the natural biotic communities worldwide (Moody and Les 2002). The cost of managing these invasive plants is enormous and it estimated around 35 billion dollars each year in the United States alone (Pimentel *et al.* 2000). The first and foremost requirement for effective management of invasive plants is their correct taxonomic identification. It is likely that an incorrect identification can lead to the inadvertent eradication of rare and non-target endemic species (Moody and Les 2008). In particular, aquatic plants are difficult to identify properly due to their inconspicuous floral characters and convergent vegetative morphology. Many aquatic plant groups still are in need of basic taxonomic treatments.

By clarifying the taxonomy of *M. aquaticum* in this Himalayan region, the present investigation should facilitate the conservation of macrophytic diversity and sustainable management of freshwater ecosystems in this biodiversity hotspot (Mittermeier 2005).

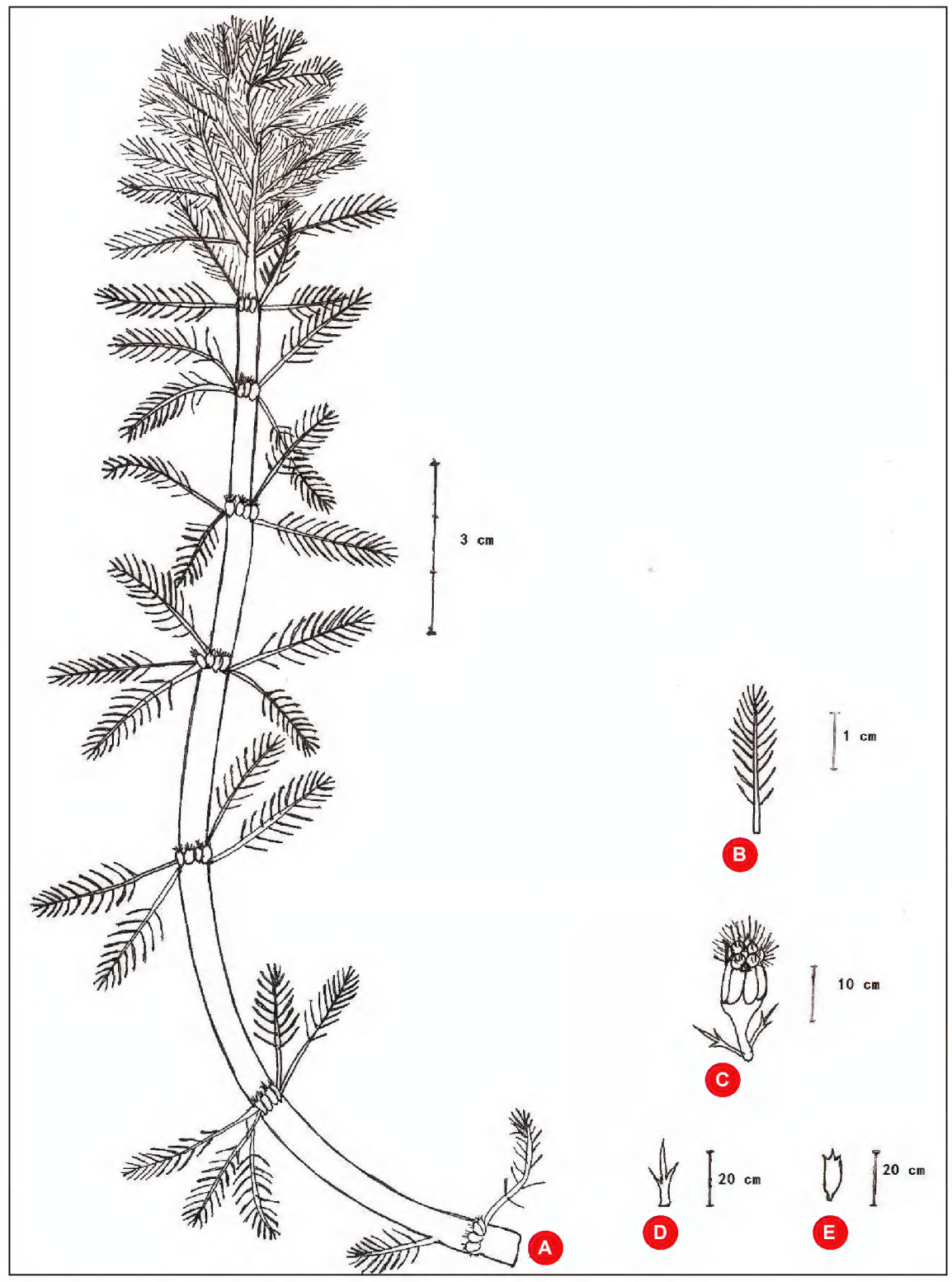

FIGURE 2. *Myriophyllum aquaticum* (Vell.) Verdc. A: Habit. B: Leaf. C: Flower. D: Bracteole. E: Sepal.

TABLE 1. Comparison of different Myriophyllum species occurring in the Kashmir Himalaya.

DIAGNOSTIC CHARACTERS	SPECIES			
	M. spicatum	*M. tuberculatum*	*M. verticillatum*	*M. aquaticum*
Habit	submerged	submerged	Submerged/emergent	Submerged/emergent
Stem	Terete, Swollen below inflorescence	Angular(nodes), Not swollen	Terete, Not swollen	Terete, Not swollen
Leaves(all pinnate)	20-40 segments, Midrib thin 4/whorl Dark green	12-28 segments, Midrib thin 2-4/whorl Dull green	18-34 segments Midrib thin 4-6/whorl green	9-29 segments Midrib thick 4-6/whorl Bright green or glaucous
Inflorescence	Monoecious spike	Monoecious spike	Monoecious spike	Dioecious (flowers axillary)
Inflorescence length	4-15 cm	3-7 cm	5-15 cm	Not applicable
Flowers/ whorl	4	unknown	5	3-6 (per node)
Bracts	Lower bracts lanceolate,upper bracts rhombic to elongate	-	Pinnate or pectinate	Absent
Bracteoles	Reniform or suborbicular	-	Pectinate or absent	Sublate, unilaciniate
Sepals	4, fused	4,ovate-oblong, mucronate	Oblong, connate	Deltoid, acute
Petals	4, caducous	4, oblong-ovate	5, obovate, obtuse	Reduced
Stamens	8	8	8	Only female flowers
Carpels	Stigma 4, plumose,white or light pink,ovary tetragonal with four deep furrows.	Pistillate flowers 4, sessile, 1-1.2 mm dia	4	4, syncarpous
Fruit	Globose, black,muricate	Subglobose, tubercled	globose	Not formed because only female plant present

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